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Hyperon production in 40 *A* GeV/*c* collisions from the NA57 experiment

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Abstract

Enhancements of strange baryon and anti-baryon yields were first observed in Pb–Pb interactions at 160 A GeV/c by WA97. The aim of the NA57 experiment is to investigate how these enhancements behave as a function of energy, and over a broader centrality range than that which was available with WA97. This paper presents a comparison of the hyperon yields in Pb–Pb interactions at 40 A GeV/c and 160 A GeV/c. Preliminary signals for the p-Be data at 40 A GeV/c are also shown.

1. The NA57 experiment

The WA97 experiment observed enhancements in the yields of strange baryons and anti-baryons when going from p-Be to Pb–Pb interactions at 160 A GeV/c [1]. These enhancements, which have been confirmed by NA57 [2], increase with the strangeness content of the particle and exceed an order of magnitude for the triply-strange Ω. Such results were predicted over 20 years ago as a signature of a phase transition to the quark–gluon plasma [3]. The goal of NA57 is to explore how this strangeness enhancement evolves, both at a reduced beam energy and as a function of centrality. NA57 collected data at 160 A GeV/c for Pb–Pb collisions over a wider centrality range than WA97, and at 40 A GeV/c for both Pb–Pb (collected in 1999) and p-Be (collected in 1999 and 2001).

The NA57 experiment has been described in detail in [4, 5]. The layout of the apparatus is shown in figure 1. The experiment was designed specifically to detect strange particles via the reconstruction of their weak decays into final states containing only charged particles. Charged tracks are detected in a 30 cm long array of silicon pixel detector planes, each having a 5 cm $\times$ 5 cm cross-section. The apparatus is placed in a 1.4 T magnetic field generated by the GOLIATH magnet in the CERN North Area. A lever arm of microstrip detectors is used to improve the momentum resolution for fast tracks. During the Pb–Pb runs the lead beam from the SPS was incident on a lead target corresponding to 1% of an interaction length. A scintillator petal detector placed behind the target provided an interaction trigger selecting the most central 60% of all Pb–Pb collisions. The event centrality, expressed as a function of the number of wounded nucleons (N_{wound}) is then determined more precisely, offline, from the charged particle multiplicity sampled in the pseudo rapidity range $2 < \eta < 4$ by two silicon strip detectors (MSDs). During the p-Be runs the proton beam from the SPS was incident on a beryllium target corresponding to 8% of an interaction length and the trigger was based on scintillator detectors at both ends of the silicon telescope, to allow triggering on at least one track or at least two tracks passing through the detector. The acceptance of the experiment corresponds to about half a unit of rapidity, at mid rapidity and medium transverse momentum.

2. Signal selection and correction procedure

Figure 2 shows the mass peaks of Λ, Ξ and Ω particles (and the corresponding anti-particles) extracted from the 40 A GeV/c Pb–Pb data. The following weak decay channels (and those

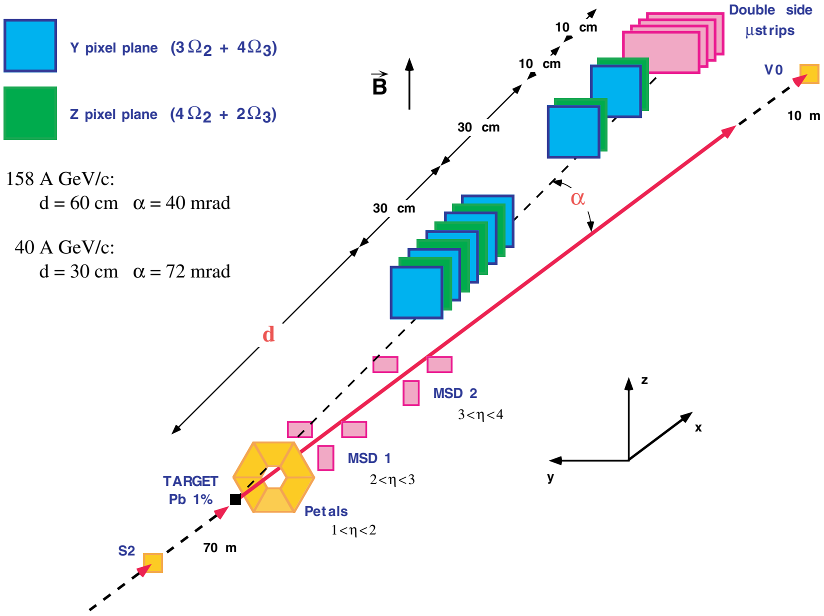

Figure 1. The NA57 experimental layout.

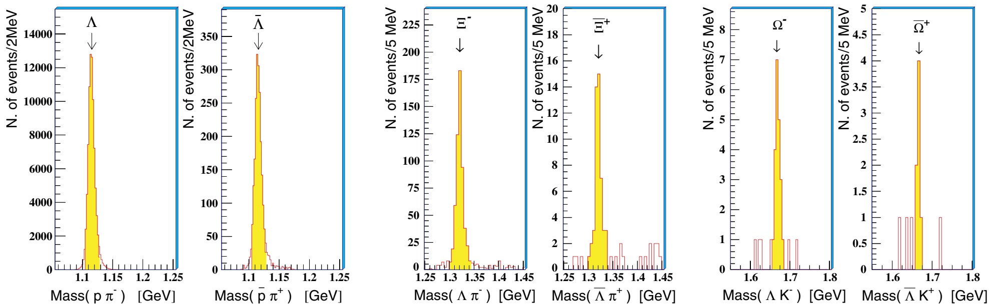

Figure 2. Hyperon signals from Pb–Pb interactions at 40 *A* GeV/*c*. Shaded regions indicate particles remaining after final mass cuts have been applied.

of the corresponding anti-particles) are detected as

$$\Lambda \to p\pi^-$$
$$\Xi^- \to \Lambda\pi^-$$
$$\Omega^- \to \Lambda K^-.$$

The Λ from a Ξ or Ω decay is then also observed via its decay into $p\pi^-$. For the analysis of Λ (and K^0) particles, oppositely charged tracks which come close together in space are used to define ‘candidates’ for a decay of that type (‘V^0’ decay). Geometric and kinematic selections are then imposed on these ‘candidates’ to derive the final signals. Similarly for Ξ and Ω decays, a charged track coming close in space to the line of flight of a reconstructed Λ forms a ‘candidate’ for a decay of that type (cascade decay). After selection cuts have been applied, a correction procedure is used in order to ‘weight’ each particle. The weighting takes into account geometric acceptance, detector and reconstruction efficiency, and undetected decay modes. The result is a correction factor which allows us to extract the yields of particles

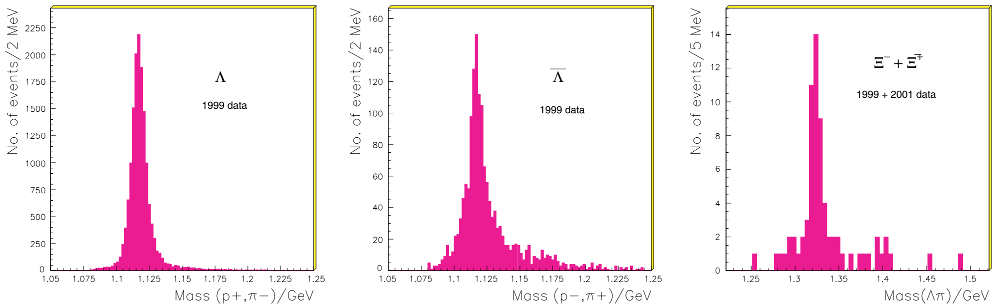

Figure 3. Preliminary hyperon signals from p-Be interactions at 40 *A* GeV/*c*.

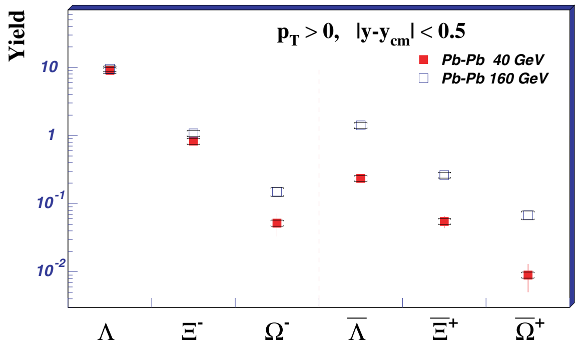

Figure 4. Yields of hyperons from Pb–Pb interactions at 40 *A* GeV/*c* and 160 *A* GeV/*c* from NA57.

produced per interaction. For the 40 *A* GeV/*c* Pb–Pb data sample, all such corrections have already been calculated.

This correction procedure has not yet been fully carried out for the 40 *A* GeV/*c* p-Be data. Figure 3 shows the preliminary signals from the 40 *A* GeV/*c* p-Be analysis; the Λ are from the p-Be data collected in 1999, and the Ξ represent the combined statistics from the runs in 1999 and 2001. Although particles with higher strangeness content are very rare in such interactions, it can be seen that it will be possible to extract yields (and, therefore, enhancements for Pb–Pb relative to p-Be) for up to the doubly-strange Ξ from these data. This will allow us to calculate the enhancements at 40 *A* GeV/*c* in the same way as those at 160 *A* GeV/*c*. In the meantime, we present here a comparison of the absolute yields in Pb–Pb collisions at 40 *A* GeV/*c* and 160 *A* GeV/*c*.

3. Results

The transverse mass $\left(m_T = \sqrt{p_T^2 + m^2}\right)$ distributions are fit with the following parameterization:

$$\frac{\mathrm{d}N}{\mathrm{d}m_T} \propto m_T \exp\left(-\frac{m_T}{T}\right)$$

where T is the inverse slope parameter and is obtained by a maximum likelihood fit. The total yields are then obtained by extrapolating over full p_T using the fitted values of the inverse slopes. Figure 4 shows the yields for Λ, Ξ and Ω, and their anti-particles, both for 40 *A* GeV/*c* and 160 *A* GeV/*c* data. Results are compared for the same centrality range, corresponding

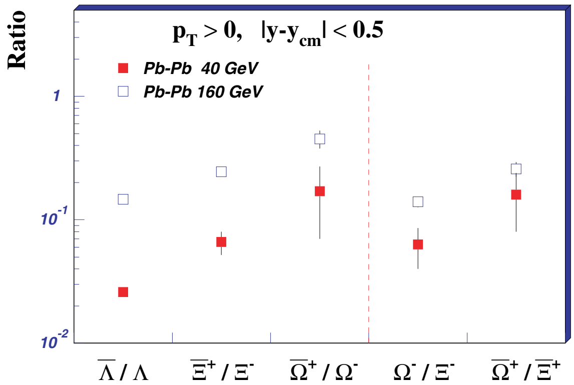

Figure 5. Ratios of hyperons from Pb–Pb interactions at 40 A GeV/c and 160 A GeV/c from NA57.

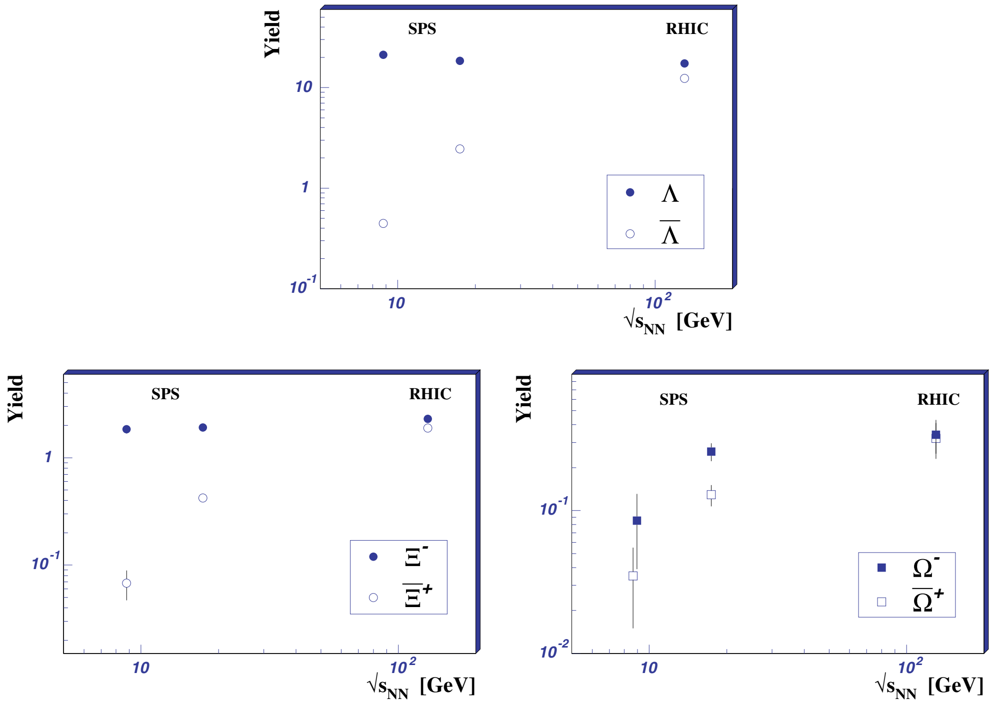

Figure 6. Hyperon yields for NA57's 40 A GeV/c and 160 A GeV/c data, and from the STAR experiment at RHIC energy of $\sqrt{s_{NN}}$ equal to 130 GeV.

to the most central 42% of the inelastic cross-section. The brackets on each point indicate the estimated systematic errors and the lines indicate the statistical errors. The comparison shows that yields for the Λ and Ξ^- remain fairly constant going from 40 A GeV/c to 160 A GeV/c, with that for the Ω^- increasing by a factor 3. The corresponding anti-particle yields all increase significantly by about a factor of 5.

In figure 5 we show the anti-particle to particle ratios. One sees that going from 40 A GeV/c to 160 A GeV/c the ratios increase, and the effect is larger for the Λ than for the more strange Ω. For the mixed ratios, a reduction of about a factor 3 can be seen for the Ω^-/Ξ^- ratio, while the Ω^+/Ξ^+ ratio is compatible within errors.

Figure 6 shows the yields for Λ, Ξ and Ω, and their anti-particles at the two energies covered by NA57 and also includes results from the STAR experiment at $\sqrt{s_{NN}}$ of 130 GeV [6–8]. For this comparison the centrality ranges taken for the NA57 points are now those which correspond roughly with the published range of the STAR data (the most central 11% for STAR's Ξ and Ω data, and the most central 5% for their Λ). Again, as the energy increases, particle yields remain almost constant, while anti-particle yields show a considerable increase with energy and this trend of the NA57 points is seen to continue towards RHIC energy.

4. Conclusions and future prospects

The results from NA57 on the production of strange baryons and anti-baryons at 40 A GeV/c have been presented and compared with those obtained at 160 A GeV/c in the same centrality range. It can be seen that while the yields of particles remain almost constant (with the exception of the Ω^- increasing by a factor of 3), those for the corresponding anti-particles increase by a factor of 5 going from 40 A GeV/c to 160 A GeV/c data.

Analysis is still ongoing on the p-Be data sample. Correction of these data will allow the enhancement factors at 40 A GeV/c to be calculated, normalizing the Pb–Pb yields to p-Be, as was done at 160 A GeV/c. It will then be possible to study the energy development of the enhancements and compare these with current models for deconfinement.

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